Kagome Spin Ice Compound

Exotic phases of matter known as spin ices are defined by frustrated spins that obey local "ice rules"—similar to electric dipoles in water ice. [20]

Nuclear techniques at ANSTO have helped to confirm a quantum spin phenomena, a Haldane phase, in a magnetic material, that has potential to be used as a measurement model for quantum computation. [19]

Lithium-ion batteries could be under threat after the development of polymer materials by the Universities of Surrey and Bristol, along with Superdielectrics Ltd, that could challenge the dominance of these traditional batteries. [18]

Researchers from Umeå University and Linköping University in Sweden have developed light-emitting electrochemical cells (LECs) that emit strong light at high efficiency. As such, the thin, flexible and lightweight LEC promises future and improved applications within home diagnostics, signage, illumination and healthcare. [17]

Physicists from the ATLAS experiment at CERN have found the first direct evidence of high energy light-by-light scattering, a very rare process in which two photons – particles of light – interact and change direction. [16]

In materials research, chemistry, biology, and medicine, chemical bonds, and especially their dynamic behavior, determine the properties of a system. These can be examined very closely using terahertz radiation and short pulses. [15]

An international collaborative of scientists has devised a method to control the number of optical solitons in microresonators, which underlie modern photonics. [14]
Solitary waves called solitons are one of nature's great curiosities: Unlike other waves, these lone wolf waves keep their energy and shape as they travel, instead of dissipating or dispersing as most other waves do.

In a new paper in Physical Review Letters (PRL), a team of mathematicians, physicists and engineers tackles a famous, 50-year-old problem tied to these enigmatic entities. [13]

Theoretical physicists studying the behavior of ultra-cold atoms have discovered a new source of friction, dispensing with a century-old paradox in the process. Their prediction, which experimenters may soon try to verify, was reported recently in Physical Review Letters. [12]

Solitons are localized wave disturbances that propagate without changing shape, a result of a nonlinear interaction that compensates for wave packet dispersion. Individual *solitons may collide, but a defining feature is that they pass through one another and emerge from the collision unaltered in shape, amplitude, or velocity, but with a new trajectory reflecting a discontinuous jump.*

Working with colleagues at the Harvard-MIT Center for Ultracold Atoms, a group led by Harvard Professor of Physics Mikhail Lukin and MIT Professor of Physics Vladan Vuletic have managed to coax photons into binding together to form molecules – a state of matter that, until recently, had been purely theoretical. The work is described in a September 25 paper in Nature.

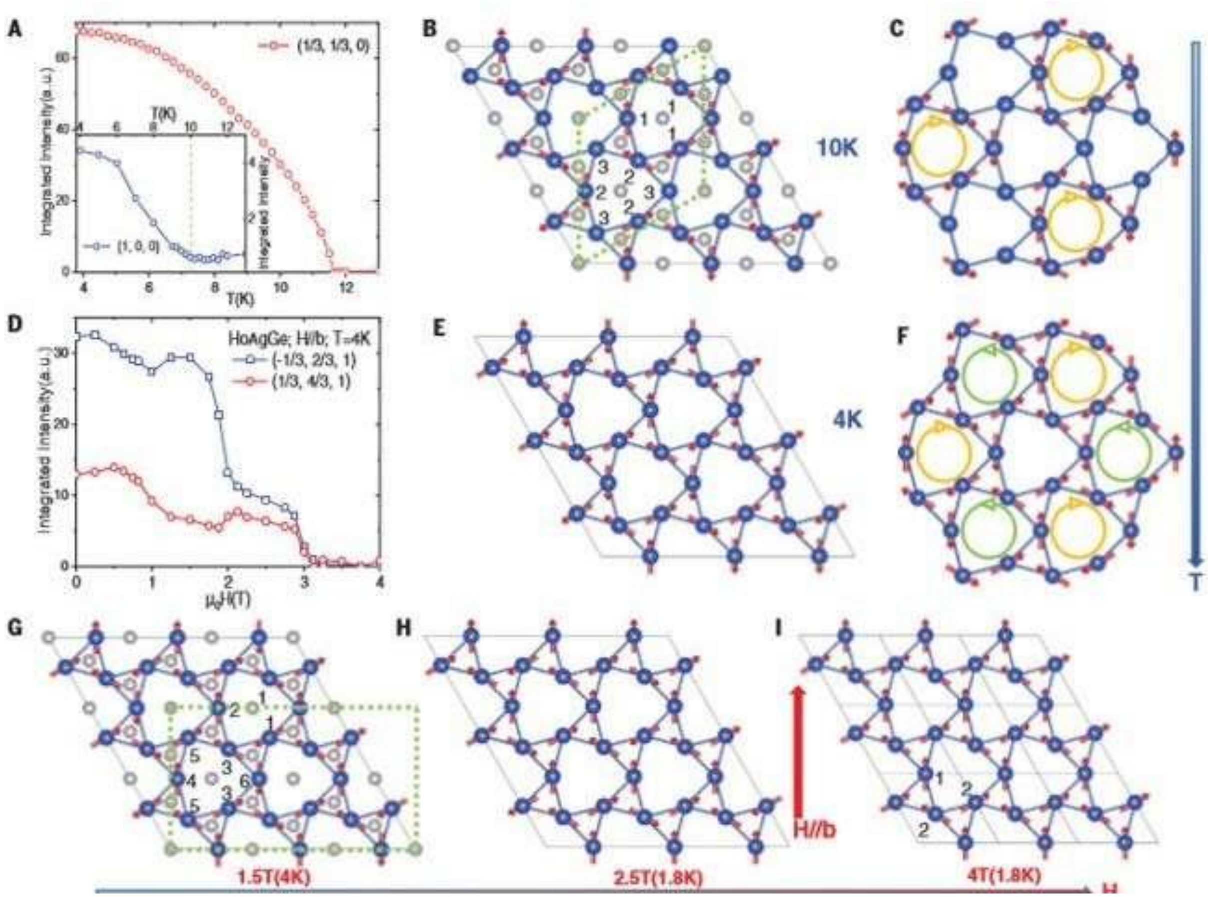
New ideas for interactions and particles: This paper examines the possibility to origin the Spontaneously Broken Symmetries from the Planck Distribution Law. This way we get a Unification of the Strong, Electromagnetic, and Weak Interactions from the interference occurrences of oscillators. Understanding that the relativistic mass change is the result of the magnetic induction we arrive to the conclusion that the Gravitational Force is also based on the electromagnetic forces, getting a Unified Relativistic Quantum Theory of all 4 Interactions.

Author: George Rajna

Realizing kagome spin ice in a frustrated intermetallic compound

Exotic phases of matter known as spin ices are defined by frustrated spins that obey local "ice rules"—similar to electric dipoles in water ice. Physicists can define ice rules in two-dimensions for in-plane Ising-like spins arranged on a kagome lattice. The ice rules can lead to diverse orders and excitations. In a new report on *Science*, Kan Zhao and a team in experimental physics, crystallography, and materials and engineering in Germany, the U.S. and the Czech Republic used experimental and theoretical approaches including magnetometry, thermodynamics, neutron scattering and Monte Carlo simulations to establish the HoAgGe crystal as a crystalline system to realize the exotic kagome spin ice state. The setup featured a variety of partially and fully ordered states as well as field-induced phases at low temperatures consistent with the kagome experimental requisites.

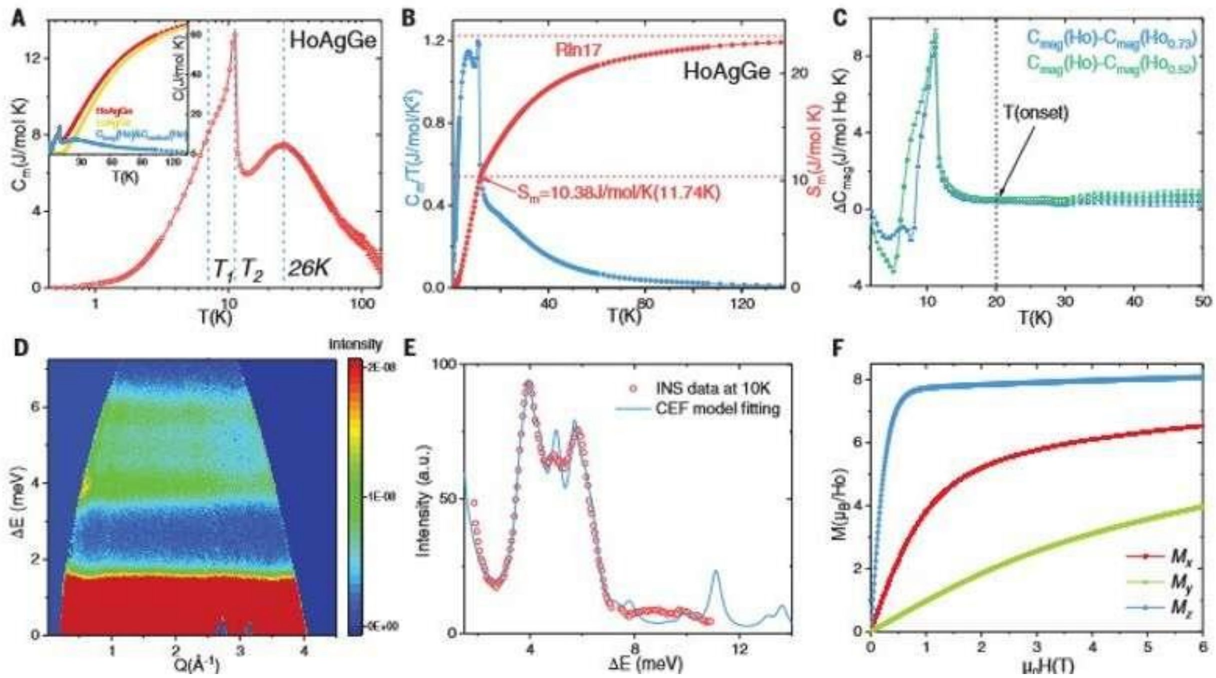
Formation of exotic phases of matter can cause frustrations in spin systems. For example, local constraints in a molecule can lead to a macroscopic number of degenerate ground states or to an extensive ground state in entropy. In two-dimensional setups, ice rules require elaborate arrangements of spins on triangular shaped kagome lattices. Consequently, the kagome spin ices showed multi-stage ordering behavior under changing temperature. Physicists had thus far only experimentally realized kagome spin ices in artificial spin ice systems formed by nanorods of ferromagnets organized into honeycomb networks. In this work. Zhao et al. used multiple experimental and theoretical approaches to demonstrate the intermetallic compound HoAgGe as a naturally existing kagome spin ice with a fully ordered ground state.



Magnetic structures of HoAgGe versus temperature and field with H//b. (A) Integrated intensity of the magnetic peak (1/3, 1/3, 0) from 13 K down to 3.8 K according to the neutron diffraction, with the integrated intensity of nuclear site (1, 0, 0) as an inset. (B) Refined magnetic structures of HoAgGe at 10 K. The magnetic unit cell is indicated by the green rhombus, with the three inequivalent Ho sites Ho1, Ho2, and Ho3 labelled by 1, 2, and 3, respectively, for simplicity.(C)Counter-clockwise hexagons of spins in the partially ordered structure of HoAgGe at 10 K, with 1/3 spins not participating in the long-range order. (D) Integrated intensity of magnetic peak (–1/3, 2/3, 1) and (1/3, 4/3, 1) versus field at 4 K. (E) Refined magnetic structure of HoAgGe at 4 K. (F) Clockwise and counter-clockwise hexagons of spins in the magnetic structure of HoAgGe at 4K,which is exactly the expected √3×√3ground state of kagome spin ice. (G) Refined magnetic structure of HoAgGe at H = 1.5 T and T = 4 K. The refinement was done in the 3 × √3 light-green rectangle. The six inequivalent Ho sites are labelled by numbers 1 to 6 for simplicity. (H) Refined magnetic structure of HoAgGe at H = 2.5 T and T = 1.8 K. (I) Refined magnetic structure of HoAgGe at H = 4 T and T = 1.8 K, with the two inequivalent Ho sites labelled by 1 and 2. The field direction is marked by the red arrow for (G) to (I). Credit: Science, doi:10.1126/science.aaw1666

The team then conducted structure and magnetometry measurements of HoAgGe. Although neutron diffraction measurements conducted in the past suggested noncollinear magnetic structures of HoAgGe—these experiments were based on powder samples that were insufficient to fully determine the magnetic structure in the presence of frustration. Zhao et al. combined neutron diffraction with thermodynamic measurements in single-crystalline HoAgGe to show its exotic temperature and magnetic-field dependent magnetic structures—consistent with the kagome ice rule. To fully determine magnetic structures from neutron diffraction based on nontrivial spin structures of HoAgGe, Zhao et al. performed single-crystal neutron diffraction experiments, down to 1.8 K. Below a high-temperature transition at 11.6 K, the team observed a magnetic peak.

When they refined the neutron data at 4 K, the team observed a more detailed magnetic structure where the fully ordered ground state indicated alternating clockwise and counter-clockwise hexagonal spins. The resulting √3 x √3 ground state precisely represented the classical kagome spin ice, as theoretically predicted. According to the kagome ice rule, the dominating nearest-neighbor ferromagnetic coupling must occur between co-planar spins with site-dependent Ising-like uniaxial anisotropy. In the present work, Zhao et al. calculated and confirmed Ising-like anisotropy of the crystalline electric field (CEF) for the HoAgGe crystals.



Magnetic specific heat and INS results of HoAgGe. (A) Magnetic contribution to the specific heat Cm of HoAgGe with the dotted lines indicating T1, T2, and a broad peak at 26 K. Note that the error bars below 30 K are smaller than the symbol sizes. (Inset) Specific heat of HoAgGe, LuAgGe, and their difference. The latter is defined as the sum of the magnetic and the nuclear contributions to the specific heat of HoAgGe. (B) Cm/T data and the corresponding magnetic entropy Sm, which approaches the theoretical value of Rln17 above 100 K. (C) Difference between the magnetic specific heat of HoAgGe and that of Lu1-xHoxAgGe (x = 0.52 and 0.73) after normalization (see text). (D) INS spectra of HoAgGe at 10 K with incident neutron wavelength 3 Å. (E) Constant Q cuts (1.4 < Q < 2.2 Å −1) showing the results of the CEF fitting to neutron-scattering data. (F) Isothermal magnetization calculated for CEF-fitting parameters at 1.5 K for three quantization axes. Credit: Science, doi:10.1126/science.aaw1666

To further confirm the authenticity of HoAgGe as a kagome spin ice, the research team investigated if established ice rules were applicable even outside the fully ordered ground state. Using neutron diffraction under magnetic fields they showed that HoAgGe satisfied these requisites and observed an increasing magnetic field with sudden changes during metamagnetic transitions. For further information, Zhao et al. refined the magnetic structures obtained from neutron scattering and noted magnetic transitions to result from the competition between the external magnetic field and weaker couplings that do not affect the ice rule.

After establishing that the kagome ice rule applied to HoAgGe crystals at low temperature, the team examined thermodynamic behaviors of kagome spin ice by isolating the magnetic contribution to specific heat by deducing contributions from the nuclei, lattice vibrations and itinerant electrons of the crystal. To determine the extent to which Ho ionic spins of the HoAgGe crystal could be viewed approximately as Ising, Zhao et al. next discussed the crystalline electric field (CEF) effects. To directly understand CEF splitting, they conducted inelastic neutron scatting (INS) experiments of HoAgGe crystals using the advanced time-of-flight spectrometer. The results indicated four low-energy CEF modes showing Ising-type anisotropy.

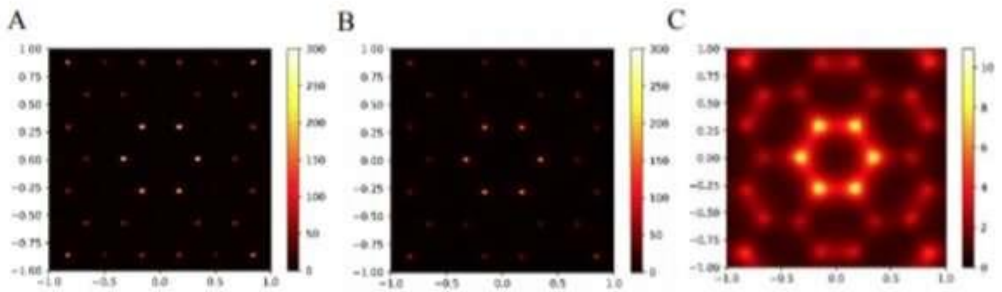
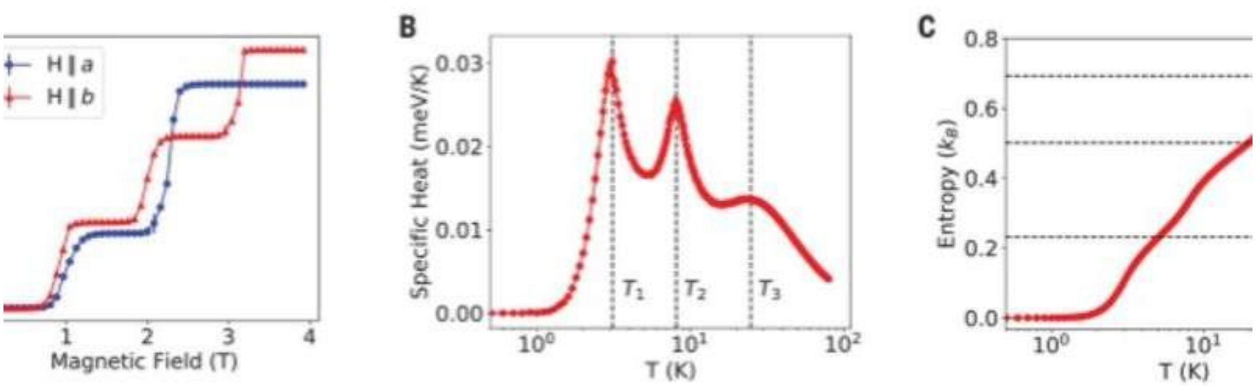


Fig. S19: Magnetic structure factor from Monte Carlo simulations in an 18×18 unit cell at (A) T=1 K, (B) T=5 K, and (C) T=15 K, respectively. The horizontal and the vertical axes are respectively (H, H, 0) and (-K, K, 0), similar as in Fig. S5.

Magnetic structure factor from Monte Carlo simulation in an 18 x 18 unit cell at (A) T= 1 K, (B) T = 5 K and (C) T = 15 K. The horizontal and vertical axes were respectively (H, H, 0) and (-K, K, 0). Credit: Science, doi:10.1126/science.aaw1666

Based on the experimental evidence, they proposed a classical spin model containing Ising-like in-plane spins on a 2-D distorted kagome lattice. Using Monte Carlo simulations of the classical spin model on an 18 x 18 lattice, they reproduced the ground state and partially ordered state to capture the classical spin model and the main characteristics of the HoAgGe magnetism at low temperatures. The model developed in the study differed from both dipolar and short-range kagome ice cases relative to exchange couplings and long-range dipolar interactions, with further investigations requiring a separate study.



Monte Carlo simulations of the 2D classical spin model for HoAgGe. (A) M(H) curves at 1 K for H along the a and b axes. (B) Temperature dependence of the specific heat per spin. (C) Magnetic entropy per spin calculated from the specific heat. The three horizontal dashed lines correspond to ln2 ≈ 0.693 (paramagnetic Ising), 0.501 (short-range ice order), and 1 3ln2≈0:231 (toroidal order), respectively. An 18 × 18 cell was used for the calculation. Credit: Science, doi:10.1126/science.aaw1666

In this way, the Monte Carlo simulations of the classical spin model only partially agreed with the experiments. The discrepancy may have resulted from multiple, low-lying CEF levels of the Ho^{3+} ions. In HoAgGe, the metallicity simultaneously suppressed CEF splitting of Ho^{3+} ions to enhance exchange coupling between them, making the two energy scales comparable to low-lying CEF levels. The resulting semi-classical model can still be mapped to an Ising model, thereby explaining the validity of the experiment. Compared to other pyrochlore spin ices, the metallic nature of HoAgGe made it a high-temperature kagome ice and may also lead to further exotic phenomena, including interactions between electric currents and magnetic monopoles as well as metallic magnetoelectric effects. [20]

Evidence of quantum state in spin cluster chain predicted by Nobel Prize recipient found in magnetic mineral

Nuclear techniques at ANSTO have helped to confirm a quantum spin phenomena, a Haldane phase, in a magnetic material, that has potential to be used as a measurement model for quantum computation.

Although there has been experimental evidence of the Haldane phase in other types of one dimensional antiferromagnetic materials, it is believed to be the first evidence in a cluster-based material.

"The neutron spectrum from Pelican provided the very data that confirmed Haldane state exists in fedotovite as proposed by our other measurements and theoretical studies. The neutron data showed both spin gap and dispersion, that are characteristics of the Haldane state," said lead author A/Prof Masayoshi Fujihara of the Tokyo University of Science.

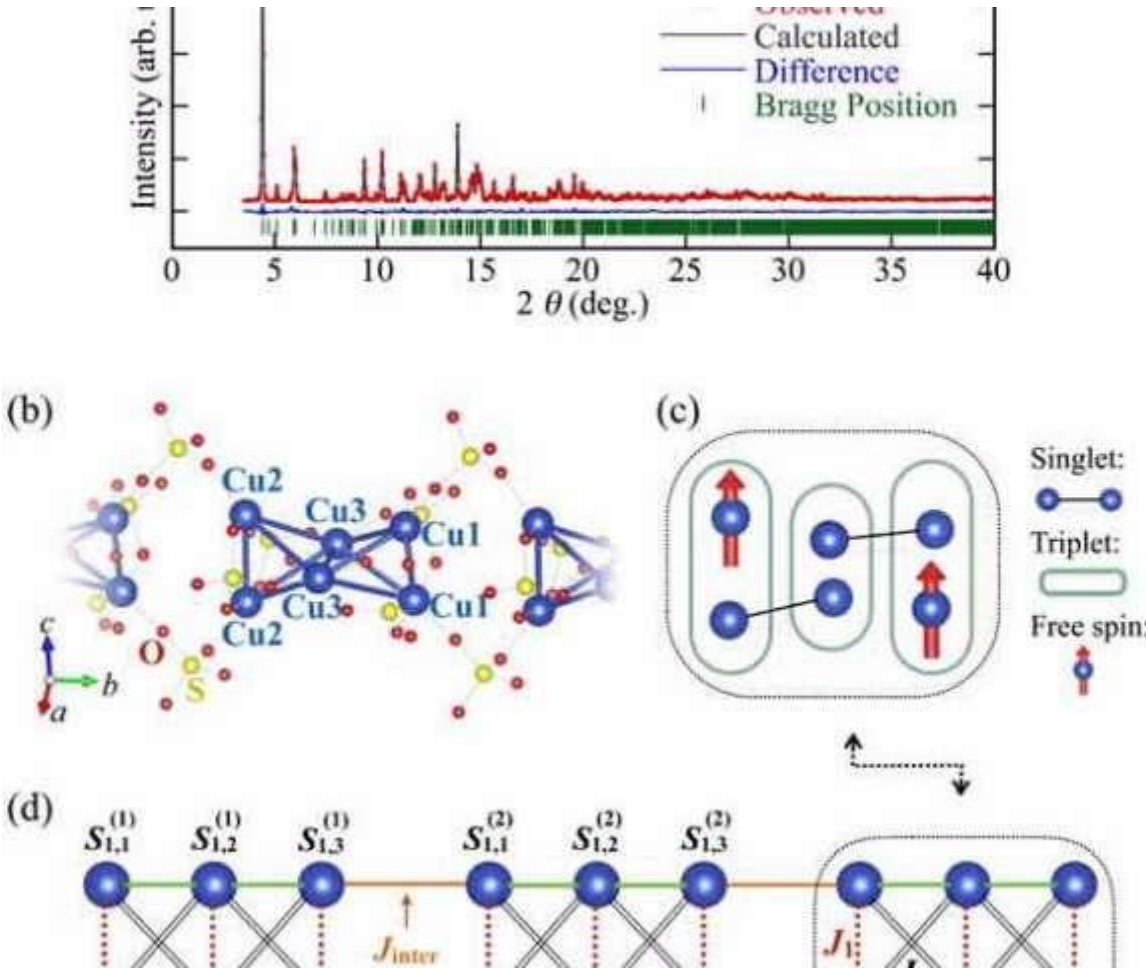
In an article published in *Physical Review Letters* as an 'Editors' Suggestion' , a large collaboration of researchers, led by physicists from Japan, ANSTO instrument scientists Drs Richard Mole, Dehong Yu and Shinichiro Yano of the National Synchrotron Radiation Research Centre in Taiwan (who operates the Taiwanese instrument Sika at ANSTO), shared experimental evidence of the Haldane phase in fedotovite.

The framework for this unusual state of matter was predicted by Prof Duncan Haldane, who shared the Nobel Prize in Physics for the development of the 'topological phases of matter theory' with David Thouless and Michael Kosterlitz in 2016.

Quasi one dimensional spin systems, such as fedotovite $K_2Cu_3O(SO_4)_3$, have an unusual magnetic behaviour at very low temperature, in which the ground state is a one-dimensional chain in a triplet configuration with S=1 spin.

The S=1 occurs because there are an even number of S=1/2 on the magnetic Cu2+ ions at the ends of spin chain, as predicted by Haldane.

"Quasi-one dimensional chains such as fedotovite do not have a single spin but a group of spins forming a cluster. One cluster of atoms then weakly interacts with the neighbouring cluster of atoms," said Mole.



Crystal structure of $K_2Cu_3O(SO_4)_3$. Credit: Australian Nuclear Science and Technology Organisation (ANSTO)

Magnetic coupling occurs because of super exchange interactions between the spin clusters and small antiferromagnetic coupling within the cluster.

"That gapped behaviour is observable in the Pelican spectrum, which is highly sensitive to weak magnetic interactions," said Mole.

The fedotovite has a unique arrangement of magnetic ions and two-stage magnetic behaviour.

Inelastic neutron scattering on the Pelican time-of-flight spectrometer captured the spin gap at 1.5 K with a magnitude of 0.6. meV which closes at 4.0 K. The measurements were in agreement with theoretical predictions.

"We are talking about very small amounts of energy but the gap is real," said Yu.

"The Haldane state will emerge whenever the number of tetrahedral in the spin cluster chain is even but not odd as predicted by our theoretical calculations in this paper," said Yano.

The crystal structure of the mineral fedotovite was originally determined by Russian scientists in the 1990's, however the current work utilised a newly developed synthetic method in the Fujiahala lab at Tokyo University of Science.

It allowed for large quantities of high purity sample to be made which was essential for the neutron scattering experiments.

The crystal structure was determined by X-ray diffraction at the Photon Factory, High Energy Accelerator Research Organization (KEK) in Japan. [19]

Alternative to traditional batteries moves a step closer to reality after exciting progress in supercapacitor technology

Lithium-ion batteries could be under threat after the development of polymer materials by the Universities of Surrey and Bristol, along with Superdielectrics Ltd, that could challenge the dominance of these traditional batteries.

Only one year ago, the partners announced scientific results for novel polymer materials that have dielectric properties 1,000 to 10,000 times greater than existing electrolytes (electrical conductors). These stunning scientific findings have now been converted into 'device' scale technical demonstrations.

Researchers from the universities achieved practical capacitance values of up to 4F/cm2 on smooth low-cost metal foil electrodes. Existing supercapacitors on the market typically reach 0.3F/cm2 depending upon complex extended surface electrodes.

More significantly, the researchers managed to achieve results of 11-20F/cm2 when the polymers were used with specially treated stainless-steel electrodes – the details of which are being kept private pending a patent application.

If these values of capacitance can be achieved in production, it could potentially see supercapacitors achieving energy densities of up to 180whr/kg—greater than lithium ion batteries.

Supercapacitors store energy using electrodes and electrolytes and both charge and deliver energy quickly – conventional batteries perform the same task in a much slower, more sustained way. Supercapacitors have the ability to charge and discharge rapidly over very large numbers of cycles. However, because existing supercapacitors have poor energy density per kilogramme (currently around one twentieth of existing battery technology), they have been unable to compete with conventional battery energy storage. Even with this restriction, supercapacitor buses are already being used in China, but the current technology means that they need to stop to be recharged frequently (i.e. at almost every bus-stop).

The team of scientists have been able to test the new materials in two ways:

By using small single layer cells charged to 1.5 volts for two to five minutes and then run demonstration devices, including a small fan.

By using a three-cell series stack that is able to be rapidly charged to five volts and operate an LED.

The University of Bristol is going much further by producing a complex series-parallel cell structure in which both the total capacitance and operating voltage can be separately controlled.

Based on these impressive results, Superdielectrics Ltd, the company behind this technology, is now looking to build a research and low volume production centre. If successful in production, the material could not only be used as a battery for future mobile devices, but could also be used in refuelling stations for electric cars.

Dr. Brendan Howlin, Senior Lecturer in Computational Chemistry at the University of Surrey, said: "These results are extremely exciting and it is hard to believe that we have come so far in such a short time. We could be at the start of a new chapter in the technology of low cost electrical energy storage that could shape the future of industry and society for many years to come."

Dr. Donald Highgate, Director of Research for Superdielectrics Ltd and alumnus of the University of Surrey, said: "These exciting results are of particular satisfaction to me because they build upon my work in hydrophilic polymers that has been a major part of my professional life; beginning in the later 1970s with extended wear soft contact lenses, and leading in the period 1990 to 2009, to fuel cells and electrolysers of exceptional efficiency.

"The present work, if it can be translated into production, promises to make rapid charging possible for electric vehicles, as well as offering a much-needed low cost method of storing the transient output from renewable energy systems. Wind, wave and solar energy is available but it is intermittent and, without storage, cannot be relied upon to meet our energy needs. This new work would transform the energy system which underpins our entire way of life – it is the necessary development before we and our children can have a genuinely sustainable, environmentally safe energy supply."

Dr. Ian Hamerton, Reader in Polymers and Composite Materials from the Department of Aerospace Engineering at the University of Bristol, commented: "Following the unveiling of the preliminary results at the first press conference just 14 months ago, the team has worked hard to increase the storage capability of these innovative materials still further. Our foremost challenge is now to translate these scientific findings into robust engineered devices and unlock their revolutionary potential." [18]

The LEC—now an efficient and bright device

Researchers from Umeå University and Linköping University in Sweden have developed light-emitting electrochemical cells (LECs) that emit strong light at high efficiency. As such, the thin, flexible and lightweight LEC promises future and improved applications within home diagnostics, signage, illumination and healthcare. The results are published in *Nature Communications*.

The light-emitting electrochemical cell (LEC) can be thin, flexible, and light-weight and be driven to essentially any emission color by the low voltage of a battery. It can also be extremely low cost, since it can be fabricated with low-cost printing and coating methods similar to how newspapers are fabricated.

A persistent problem is that it has not been possible to attain strong brightness at high efficiency from LEC devices. In fact, it has been questioned whether the LEC is even capable of being simultaneously bright and efficient. In the current issue of *Nature Communications*, a team of scientists demonstrate a path toward resolving this problem. Using a systematic combination of experiments and simulations, they have established a generic set of design principles, including balanced trap depths, optimized doping, and electrochemically stabile materials. The approach has paved the way for LEC devices that emit light with a high brightness of 2,000 cd/m^2 at an electron-to-photon efficiency of 27.5 percent.

"As a point of reference, a normal TV operates between 300 to 500 cd/m^2, while 2,000 cd/m^2 is the typical brightness of an OLED illumination panel. Concerning efficiency, our LEC device is close to that of common fluorescent tubes," says Ludvig Edman, leader of the project and professor at the department of physics at Umeå University.

"With this performance, the LEC component is now not only offering low costs and highly attractive design advantages, but is also becoming a true competitor with existing technologies, such as the fluorescent tube, LED and OLED, as regards to efficient and practical operation," says Martijn Kemerink, professor at the department of physics, chemistry and biology at Linköping University. [17]

ATLAS observes direct evidence of light-by-light scattering

Physicists from the ATLAS experiment at CERN have found the first direct evidence of high energy light-by-light scattering, a very rare process in which two photons – particles of light – interact and change direction. The result, published today in Nature Physics, confirms one of the oldest predictions of quantum electrodynamics (QED).

"This is a milestone result: the first direct evidence of light interacting with itself at high energy," says Dan Tovey(University of Sheffield), ATLAS Physics Coordinator. "This phenomenon is impossible in classical theories of electromagnetism; hence this result provides a sensitive test of our understanding of QED, the quantum theory of electromagnetism."

Direct evidence for light-by-light scattering at high energy had proven elusive for decades – until the Large Hadron Collider's second run began in 2015. As the accelerator collided lead ions at unprecedented collision rates, obtaining evidence for light-by-light scattering became a real possibility. "This measurement has been of great interest to the heavy-ion and high-energy physics communities for several years, as calculations from several groups showed that we might achieve a significant signal by studying lead-ion collisions in Run 2," says Peter Steinberg (Brookhaven National Laboratory), ATLAS Heavy Ion Physics Group Convener.

Heavy-ion collisions provide a uniquely clean environment tostudy light-by-light scattering. As bunches of lead ions are accelerated, an enormous flux of surrounding photons is generated. When ions meet at the centre of the ATLAS detector, very few collide, yet their surrounding photons can interact and scatter off one another. These interactions are known as 'ultra-peripheral collisions'.

Studying more than 4 billion events taken in 2015, the ATLAS collaboration found 13 candidates for light-by-light scattering. This result has a significance of 4.4 standard deviations, allowing the ATLAS collaboration to report the first direct evidence of this phenomenon at high energy.

"Finding evidence of this rare signature required the development of a sensitive new 'trigger' for the ATLAS detector," says Steinberg. "The resulting signature—two photons in an otherwise empty detector—is almost the diametric opposite of the tremendously complicated eventstypically expected from lead nuclei collisions. The new trigger's success in selecting these events demonstrates the power and flexibility of the system, as well as the skill and expertise of the analysis and trigger groups who designed and developed it."

ATLAS physicists will continue to study light-by-light scattering during the upcoming LHC heavy-ion run, scheduled for 2018. More data will further improve the precision of theresult and may open a new window to studies of new physics. In addition, the study of ultra-peripheral collisions should play a greater role in the LHC heavy-ion programme, as collision rates further increase in Run 3 and beyond. [16]

Inspecting matter using terahertz light

In materials research, chemistry, biology, and medicine, chemical bonds, and especially their dynamic behavior, determine the properties of a system. These can be examined very closely using terahertz radiation and short pulses. KIT's FLUTE accelerator will be used for the development of new accelerator technologies for compact and powerful terahertz sources that are supposed to serve as efficient research and application tools.

"The KIT scientists excel in their ability to come up with creative ideas and explore new fields of application," as Professor Holger Hanselka, President of KIT, points out. "With the compact FLUTE accelerator, KIT opens the door to a new tool that will enable biologists, analytical chemists, and materials scientists to obtain outstanding insights."

The FLUTE facility (this abbreviation is derived from its German name: Ferninfrarot Linac- und TestExperiment) is a development platform for accelerator physics studies. It will serve as a test facility for methods that allow, in a first step, to better understand, measure, and control the complex dynamics of ultra-short electron bunches. Only very compact electron bunches can generate intensive, brilliant, and coherent terahertz radiation. The special challenge faced when designing accelerators such as FLUTE is to keep the electron cloud so compact during the acceleration process that its expansion is smaller than the wavelength of the generated electromagnetic radiation. Only then, the waves overlap each other, forming pulses of high intensity with a duration of picoseconds or femtoseconds.

In the long run, control of the electron bunches must be improved in such a way that the terahertz radiation can be adapted perfectly to the intended application. Terahertz radiation could open up new domains of application for which the neighboring visible light and radio waves are unsuitable. As a research infrastructure, FLUTE will also be used for the development of terahertz radiation measuring methods that can be employed in materials and life sciences. Protein oscillations can be examined just as well as the behavior of superconductors or novel semiconductors.

Within the FLUTE accelerator, whose length is approx. 12 meters, the electrons are accelerated to reach an energy of up to 50 MeV. The electron cloud is compressed to a few micrometers so that radiation with a frequency of 30 terahertz or more can be generated. Besides the Institute for

Beam Physics and Technology at KIT, development partners from all over Europe, above all the Swiss Paul
Scherrer Institute (PSI), participate in the FLUTE project. [15]

Scientists develop new method of high-precision optical measurement

An international collaborative of scientists has devised a method to control the number of optical solitons in microresonators, which underlie modern photonics.

Photonics is a dynamically developing field of modern physics. Microresonators are basic structural elements of photonics, an integral part of almost all sophisticated optical and microwave devices. In fact, resonators are circular light traps. Microresonators are currently used for laser stabilization and optical filters.

In their research, the results of which are published in Nature Physics, the scientists have addressed the problem of stable optical pulse generation in resonators—in other words, to ensure that every pulse (soliton) put into it persists for a long period of time. The second experimental aim was to reduce the number of soliton pulses moving in a resonator to one. At the same time, the outgoing emission spectrum has the appearance of a super-stable optical frequency comb, which could be used as a high-precision ruler for optical spectra.

Grigory Lichachev, a doctoral student at the Faculty of Physics, said, "Pulses should live for a long period of time, and it should be only one, not several pulses.

When there is only one pulse, it has the clearest spectrum, known as a comb, which has many applications, for instance, in spectroscopy."

The scientists studied two optical resonators on a chip base only one micron thick. The first one was made out of optical crystal, magnesium fluoride (MgF_2); the second one out of silicon nitride (Si_3N_4).

A laser was introduced light into the resonator, and the properties of its pulses were measured at output with the help of spectrometer.

The experiment demonstrated a method that forms one pulse, which propagates around in a resonator. Physicists observed a regular spectral comb, which is the distinguishing characteristic of a soliton. Moreover, the article shows a new and very effective method worked out by scientists to observe solitons in real-time. This was achieved by the addition of weak phase modulation to the input signal and further response registration to this disturbance. Such an approach opens up new possibilities for maintaining and stabilizing combs.

The technique worked out by the scientists actuates an unknown large number of solitons in a resonator and then sequentially reduces this number to a single pulse.

The scientists emphasize that the reduction of extra solitons sequentially becomes possible only due to the change of laser frequency used for actuating the resonator.

The optical frequency comb is the foundation of the laser-based precision spectroscopy technique, which was awarded the Nobel Prize for Physics in 2005.

Applications include astronomy and high-precision sensors, for instance, to measure the spectrum of an unknown substance. Using two identical optical solitons and overlapping their optical frequency combs, scientists could measure optical frequencies, which could not be measured directly because of their size.

Potential applications of this method include the measurement of gas composition using spectroscopy in the mid-infrared range. By directing two optical solitons to the experimental gas through a common optical fiber, scientists could observe notches, connected with specific absorption lines, in the spectrum output.

Usage of two solitons allows scientists to measure frequencies in radio waves beyond the optical range. If it takes seconds to measure frequencies in an optical spectrometer, then in the microwave range, the measurement time is nanoseconds. [14]

Study solves 50-year-old puzzle tied to enigmatic, lone wolf waves

Solitary waves called solitons are one of nature's great curiosities: Unlike other waves, these lone wolf waves keep their energy and shape as they travel, instead of dissipating or dispersing as most other waves do.

In a new paper in Physical Review Letters (PRL), a team of mathematicians, physicists and engineers tackles a famous, 50-year-old problem tied to these enigmatic entities.

The puzzle dates back to 1965, when physicists Norman Zabusky and Martin Kruskal came up with a surprising solution to the Korteweg-de Vries equation, which serves as a mathematical model for describing nonlinear waves in shallow water.

Using a computer, Zabusky and Kruskal generated an approximate solution to the equation that featured eight independent, particle-like waves. Each of these waves retained its form and speed over time and distance—even after colliding with other such waves. The colleagues coined the term "soliton" to describe these unusual entities, giving birth to modern research in this field.

Kruskal and others then went on to invent a new mathematical method to solve the Korteweg-de Vries equation exactly. However, the calculations needed to obtain concrete answers are complex, typically requiring the use of a computer to complete—thus limiting scientists' ability to understand phenomena, including Zabusky and Kruskal's 1965 solution, says University at Buffalo mathematician Gino Biondini.

Moreover, to Biondini's knowledge, the original wave pattern that Zabusky and Kruskal described in 1965 has never been fully reproduced in the physical world (though earlier experiments have managed to generate portions of the solution).

The new PRL study, published Sept. 28, addresses both of these problems, says Biondini, a co-author on the paper.

A new approach to an old problem

With Guo Deng, a UB PhD candidate in physics, Biondini developed a mathematical approach that produces an approximate solution to the equation that Zabusky and Kruskal tackled in the 1960s. The new approach enables researchers to make explicit, accurate predictions about how many solitons will emerge in a given setting, as well as what features these waves will have, such as their amplitude and speed.

The method's simplicity means that researchers can use it to gain a better mathematical understanding of soliton formation in these kinds of situations, Biondini says.

"Zabusky and Kruskal's famous work from the 1960s gave rise to the field of soliton theory," says Biondini, a professor of mathematics in the UB College of Arts and Sciences. "But until now, we lacked a simple explanation for what they described. Our method gives you a full description of the solution that they observed, which means we can finally gain a better understanding of what's happening."

Making waves

While Biondini and Deng worked on the theoretical side of the problem, colleagues in Europe and Japan put their math to the test in real-world experiments as part of the same paper.

Led by Italian scientists Miguel Onorato and Stefano Trillo of the University of Turin and the University of Ferrara, respectively, the team ran experiments in a 110-meter-long water tank in Berlin using a computer-assisted wave generator. The wave patterns they produced matched well with Biondini and Deng's predictions, and included the original eight-soliton solution described by Zabusky and Kruskal so many years before (though it should be noted that water waves do begin to lose some energy after traveling over long distances, and are therefore only approximately solitons).

"Previous experiments had produced parts of the famous results from 1965, but, as far as I know, they all had limitations," Onorato says. "We were able to generate the solution more fully, including all eight solitons. We were also able to experimentally generate another feature observed in multisoliton solutions, namely the strange phenomenon of recurrence, in which a wave pattern transitions from its initial state to a state with several solitons and back again to the original state. This is akin to placing a bunch of children in a room to play, then returning later to find that the room has been returned to its initial, tidy state after a period of messiness." [13]

Ultra-cold atoms may wade through quantum friction

Theoretical physicists studying the behavior of ultra-cold atoms have discovered a new source of friction, dispensing with a century-old paradox in the process. Their prediction, which experimenters may soon try to verify, was reported recently in Physical Review Letters.

The friction afflicts certain arrangements of atoms in a Bose-Einstein Condensate (BEC), a quantum state of matter in which the atoms behave in lockstep. In this state, well-tuned magnetic fields can cause the atoms to attract one another and even bunch together, forming a single composite particle known as a soliton.

Solitons appear in many areas of physics and are exceptionally stable. They can travel freely, without losing energy or dispersing, allowing theorists to treat them like everyday, non-quantum objects. Solitons composed of photons—rather than atoms—are even used for communication over optical fibers.

Studying the theoretical properties of solitons can be a fruitful avenue of research, notes Dmitry Efimkin, the lead author of the paper and a former JQI postdoctoral researcher now at the University of Texas at Austin. "Friction is very fundamental, and quantum mechanics is now quite a well-tested theory," Efimkin says. "This work investigates the problem of quantum friction for solitons and marries these two fundamental areas of research."

Efimkin, along with JQI Fellow Victor Galitski and Johannes Hofmann, a physicist at the University of Cambridge, sought to answer a basic question about soliton BECs: Does an idealized model of a soliton have any intrinsic friction?

Prior studies seemed to say no. Friction arising from billiard-ball-like collisions between a soliton and stray quantum particles was a possibility, but the mathematics prohibited it. For a long time, then, theorists believed that the soliton moved through its cloudy quantum surroundings essentially untouched.

But those prior studies did not give the problem a full quantum consideration, Hofmann says. "The new work sets up a rigorous quantum-mechanical treatment of the system," he says, adding that this theoretical approach is what revealed the new frictional force.

It's friction that is familiar from a very different branch of physics. When a charged particle, such as an electron, is accelerated, it emits radiation. A long-known consequence is that the electron will experience a friction force as it is accelerated, caused by the recoil from the radiation it releases.

Instead of being proportional to the speed of the electron, as is friction like air resistance, this force instead depends on the jerk—the rate at which the electron's acceleration is changing. Intriguingly, this is the same frictional force that appears in the quantum treatment of the soliton, with the soliton's absorption and emission of quantum quasiparticles replacing the electron's emission of radiation.

At the heart of this frictional force, however, lurks a problem. Including it in the equations describing the soliton's motion—or an accelerated electron's—reveals that the motion in the present depends on events in the future, a result that inverts the standard concept of causality. It's a situation that has puzzled physicists for decades.

The team tracked down the origin of these time-bending predictions and dispensed with the paradox. The problem arises from a step in the calculation that assumes the friction force only depends on the current state of the soliton. If, instead, it also depends on the soliton's past trajectory, the paradox disappears.

Including this dependence on the soliton's history leads to nearly the same equations governing its motion, and those equations still include the new friction. It's as if the quantum background retains a memory of the soliton's path.

Hofmann says that BECs provide a pristine system to search for the friction. Experimenters can apply lasers that set the atomic soliton in motion, much like a marble rolling around a bowl—although the bowl is tightly squeezed in one dimension. Observing the frequency and amplitude of this motion, as well as how it changes over time, could reveal the friction's signature. "Using some typical experimental parameters, we think that the magnitude of this force is large enough to be observable in current experiments," Hofmann says. [12]

'Matter waves' move through one another but never share space

Physicist Randy Hulet and colleagues observed a strange disappearing act during collisions between forms of Bose Einstein condensates called solitons. In some cases, the colliding clumps of matter appear to keep their distance even as they pass through each other. How can two clumps of matter pass through each other without sharing space? Physicists have documented a strange disappearing act by colliding Bose Einstein condensates that appear to keep their distance even as they pass through one another.

BECs are clumps of a few hundred thousand lithium atoms that are cooled to within one-millionth of a degree above absolute zero, a temperature so cold that the atoms march in lockstep and act as a single "matter wave." Solitons are waves that do not diminish, flatten out or change shape as they move through space. To form solitons, Hulet's team coaxed the BECs into a configuration where the attractive forces between lithium atoms perfectly balance the quantum pressure that tends to spread them out.

The researchers expected to observe the property that a pair of colliding solitons would pass though one another without slowing down or changing shape. However, they found that in certain collisions, the solitons approached one another, maintained a minimum gap between themselves, and then appeared to bounce away from the collision.

Hulet's team specializes in experiments on BECs and other ultracold matter. They use lasers to both trap and cool clouds of lithium gas to temperatures that are so cold that the matter's behavior is dictated by fundamental forces of nature that aren't observable at higher temperatures.

To create solitons, Hulet and postdoctoral research associate Jason Nguyen, the study's lead author, balanced the forces of attraction and repulsion in the BECs.

Cameras captured images of the tiny BECs throughout the process. In the images, two solitons oscillate back and forth like pendulums swinging in opposite directions. Hulet's team, which also included graduate student De Luo and former postdoctoral researcher Paul Dyke, documented thousands of head-on collisions between soliton pairs and noticed a strange gap in some, but not all, of the experiments.

Many of the events that Hulet's team measures occur in one-thousandth of a second or less. To confirm that the "disappearing act" wasn't causing a miniscule interaction between the soliton pairs -- an interaction that might cause them to slowly dissipate over time -- Hulet's team tracked one of the experiments for almost a full second.

The data showed the solitons oscillating back and fourth, winking in and out of view each time they crossed, without any measurable effect.

"This is great example of a case where experiments on ultracold matter can yield a fundamental new insight," Hulet said. "The phase-dependent effects had been seen in optical experiments, but there has been a misunderstanding about the interpretation of those observations." [11]

Photonic molecules

Working with colleagues at the Harvard-MIT Center for Ultracold Atoms, a group led by Harvard Professor of Physics Mikhail Lukin and MIT Professor of Physics Vladan Vuletic have managed to coax photons into binding together to form molecules – a state of matter that, until recently, had been purely theoretical. The work is described in a September 25 paper in Nature.

The discovery, Lukin said, runs contrary to decades of accepted wisdom about the nature of light. Photons have long been described as massless particles which don't interact with each other – shine two laser beams at each other, he said, and they simply pass through one another.

"Photonic molecules," however, behave less like traditional lasers and more like something you might find in science fiction – the light saber.

"Most of the properties of light we know about originate from the fact that photons are massless, and that they do not interact with each other," Lukin said. "What we have done is create a special type of medium in which photons interact with each other so strongly that they begin to act as though they have mass, and they bind together to form molecules. This type of photonic bound state has been discussed theoretically for quite a while, but until now it hadn't been observed. [9]

The Electromagnetic Interaction

This paper explains the magnetic effect of the electric current from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the electric wire. The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories. [2]

Asymmetry in the interference occurrences of oscillators

The asymmetrical configurations are stable objects of the real physical world, because they cannot annihilate. One of the most obvious asymmetry is the proton – electron mass rate $M_p = 1840\ M_e$ while they have equal charge. We explain this fact by the strong interaction of the proton, but how remember it his strong interaction ability for example in the H – atom where are only electromagnetic interactions among proton and electron.

This gives us the idea to origin the mass of proton from the electromagnetic interactions by the way interference occurrences of oscillators. The uncertainty relation of Heisenberg makes sure that the particles are oscillating.

The resultant intensity due to n equally spaced oscillators, all of equal amplitude but different from one another in phase, either because they are driven differently in phase or because we are looking at them an angle such that there is a difference in time delay:

(1) $I = I_0 \sin^2 n\,\varphi/2 \,/\, \sin^2 \varphi/2$

If φ is infinitesimal so that $\sin\varphi = \varphi$ than

(2) $\iota = n^2 \iota_0$

This gives us the idea of

(3) $M_p = n^2 M_e$

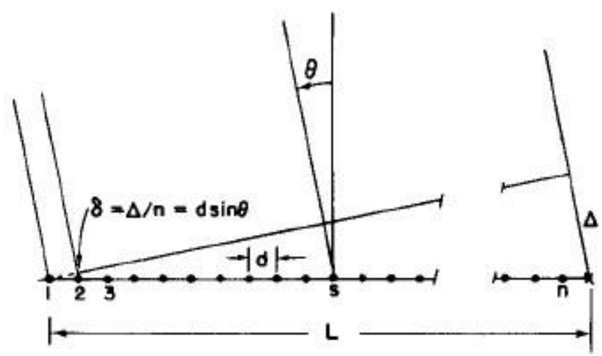


Fig. 30–3. A linear array of *n* equal oscillators, driven with phases $\alpha_s = s\alpha$.

Figure 1.) A linear array of n equal oscillators

There is an important feature about formula (1) which is that if the angle φ is increased by the multiple of 2π it makes no difference to the formula.

So

(4) $d \sin \Theta = m \lambda$ and we get m-order beam if λ less than d. [6]

If d less than λ we get only zero-order one centered at $\Theta = 0$. Of course, there is also a beam in the opposite direction. The right chooses of d and λ we can ensure the conservation of charge.

For example

(5) $2(m+1) = n$

Where $2(m+1) = N_p$ number of protons and $n = N_e$ number of electrons.

In this way we can see the H_2 molecules so that 2n electrons of n radiate to 4(m+1) protons, because $d_e > \lambda_e$ for electrons, while the two protons of one H_2 molecule radiate to two electrons of them, because of $d_e < \lambda_e$ for this two protons.

To support this idea we can turn to the Planck distribution law, that is equal with the Bose – Einstein statistics.

Spontaneously broken symmetry in the Planck distribution law

The Planck distribution law is temperature dependent and it should be true locally and globally. I think that Einstein's energy-matter equivalence means some kind of existence of electromagnetic oscillations enabled by the temperature, creating the different matter formulas, atoms molecules, crystals, dark matter and energy.

Max Planck found for the black body radiation

As a function of wavelength (λ), Planck's law is written as:

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}.$$

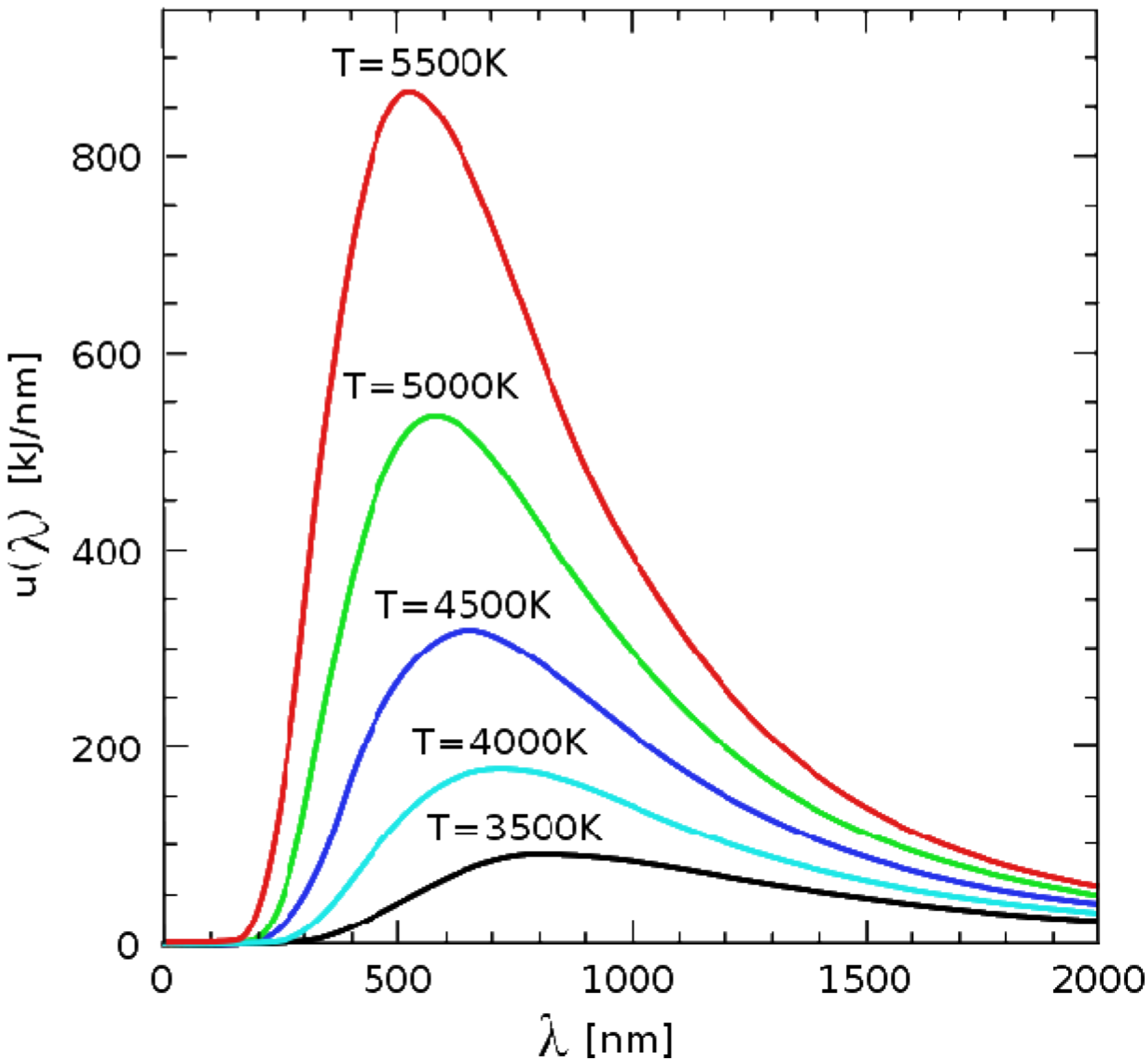


Figure 2. The distribution law for different T temperatures

We see there are two different λ_1 and λ_2 for each T and intensity, so we can find between them a d so that $\lambda_1 < d < \lambda_2$.

We have many possibilities for such asymmetrical reflections, so we have many stable oscillator configurations for any T temperature with equal exchange of intensity by radiation. All of these configurations can exist together. At the λ_{max} is the annihilation point where the configurations are symmetrical. The λ_{max} is changing by the Wien's displacement law in many textbooks.

(7) $$\lambda_{\max} = \frac{b}{T}$$

where λ_{max} is the peak wavelength, *T* is the absolute temperature of the black body, and *b* is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977685(51)\times10^{-3}$ m·K (2002 CODATA recommended value).

By the changing of T the asymmetrical configurations are changing too.

The structure of the proton

We must move to the higher T temperature if we want look into the nucleus or nucleon arrive to $d<10^{-13}$ cm. If an electron with $\lambda_e < d$ move across the proton then by (5) 2 (m+1) = n with m = 0 we get n = 2 so we need two particles with negative and two particles with positive charges. If the proton can fraction to three parts, two with positive and one with negative charges, then the reflection of oscillators are right. Because this very strange reflection where one part of the proton with the electron together on the same side of the reflection, the all parts of the proton must be quasi lepton so $d > \lambda_q$. One way dividing the proton to three parts is, dividing his oscillation by the three direction of the space. We can order 1/3 e charge to each coordinates and 2/3 e charge to one plane oscillation, because the charge is scalar. In this way the proton has two +2/3 e plane oscillation and one linear oscillation with -1/3 e charge. The colors of quarks are coming from the three directions of coordinates and the proton is colorless. The flavors of quarks are the possible oscillations differently by energy and if they are plane or linear oscillations. We know there is no possible reflecting two oscillations to each other which are completely orthogonal, so the quarks never can be free, however there is an asymptotic freedom while their energy are increasing to turn them to the orthogonally. If they will be completely orthogonal then they lose this reflection and take new partners from the vacuum. Keeping the symmetry of the vacuum the new oscillations are keeping all the conservation laws, like charge, number of baryons and leptons. The all features of gluons are coming from this model. The mathematics of reflecting oscillators show Fermi statistics.

Important to mention that in the Deuteron there are 3 quarks of +2/3 and -1/3 charge, that is three u and d quarks making the complete symmetry and because this its high stability.

The Pauli Exclusion Principle says that the diffraction points are exclusive!

The Strong Interaction

Confinement and Asymptotic Freedom

For any theory to provide a successful description of strong interactions it should simultaneously exhibit the phenomena of confinement at large distances and asymptotic freedom at short distances. Lattice calculations support the hypothesis that for non-abelian gauge theories the two domains are analytically connected, and confinement and asymptotic freedom coexist.
Similarly, one way to show that QCD is the correct theory of strong interactions is that the coupling extracted at various scales (using experimental data or lattice simulations) is unique in the sense that its variation with scale is given by the renormalization group. [4]

Lattice QCD gives the same results as the diffraction theory of the electromagnetic oscillators, which is the explanation of the strong force and the quark confinement. [1]

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T-symmetry breaking. This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with ½ spin creating; it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of

Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. A good example of this is the neutron decay, creating more particles with less known information about them.

The neutrino oscillation of the Weak Interaction shows that it is a general electric dipole change and it is possible to any other temperature dependent entropy and information changing diffraction pattern of atoms, molecules and even complicated biological living structures.

We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too. This gives the limited lifetime for the biological constructions also by the arrow of time. There should be a new research space of the Quantum Information Science the 'general neutrino oscillation' for the greater then subatomic matter structures as an electric dipole change.

There is also connection between statistical physics and evolutionary biology, since the arrow of time is working in the biological evolution also.

The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. So the Weak Interaction has two directions, samples for one direction is the Neutron decay, and Hydrogen fusion is the opposite direction. [5]

Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing.

The Higgs boson or Higgs particle is a proposed elementary particle in the Standard Model of particle physics. The Higgs boson's existence would have profound importance in particle physics because it would prove the existence of the hypothetical Higgs field - the simplest of several proposed explanations for the origin of the symmetry-breaking mechanism by which elementary particles gain mass. [3]

The fermions' spin

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light.

The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = d x d p or 1/2 h = d t d E, that is the value of the basic energy status.

What are the consequences of this in the weak interaction and how possible that the neutrinos' velocity greater than the speed of light?

The neutrino is the one and only particle doesn't participate in the electromagnetic interactions so we cannot expect that the velocity of the electromagnetic wave will give it any kind of limit.

The neutrino is a 1/2spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with ½ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and
makes possible a different time dilation as of the special relativity.

The source of the Maxwell equations

The electrons are accelerating also in a static electric current because of the electric force, caused by the potential difference. The magnetic field is the result of this acceleration, as you can see in [2].

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed.

Also an interesting question, how the changing magnetic field creates a negative electric field? The answer also the accelerating electrons will give. When the magnetic field is increasing in time by increasing the electric current, then the acceleration of the electrons will increase, decreasing the charge density and creating a negative electric force. Decreasing the magnetic field by decreasing the electric current will decrease the acceleration of the electrons in the electric current and increases the charge density, creating an electric force also working against the change. In this way we have explanation to all interactions between the electric and magnetic forces described in the Maxwell equations.

The second mystery of the matter is the mass. We have seen that the acceleration change of the electrons in the flowing current causing a negative electrostatic force. This is the cause of the relativistic effect - built-in in the Maxwell equations - that is the mass of the electron growing with its acceleration and its velocity never can reach the velocity of light, because of this growing negative electrostatic force. The velocity of light is depending only on 2 parameters: the magnetic permeability and the electric permittivity.

There is a possibility of the polarization effect created by electromagnetic forces creates the negative and positive charges. In case of equal mass as in the electron-positron pair it is simply, but on higher energies can be asymmetric as the electron-proton pair of neutron decay by week interaction and can be understood by the Feynman graphs.

Anyway the mass can be electromagnetic energy exceptionally and since the inertial and gravitational mass are equals, the gravitational force is electromagnetic force and since only the magnetic force is attractive between the same charges, is very important for understanding the gravitational force.

The Uncertainty Relations of Heisenberg gives the answer, since only this way can be sure that the particles are oscillating in some way by the electromagnetic field with constant energies in the atom indefinitely. Also not by chance that the uncertainty measure is equal to the fermions spin, which is one of the most important feature of the particles. There are no singularities, because the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greatest proton mass.

The Special Relativity

The mysterious property of the matter that the electric potential difference is self maintained by the accelerating electrons in the electric current gives a clear explanation to the basic sentence of the relativity that is the velocity of the light is the maximum velocity of the matter. If the charge could move faster than the electromagnetic field than this self maintaining electromagnetic property of the electric current would be failed. [8]

The Heisenberg Uncertainty Principle

Moving faster needs stronger acceleration reducing the dx and raising the dp. It means also mass increasing since the negative effect of the magnetic induction, also a relativistic effect!

The Uncertainty Principle also explains the proton – electron mass rate since the dx is much less requiring bigger dp in the case of the proton, which is partly the result of a bigger mass m_p because of the higher electromagnetic induction of the bigger frequency (impulse).

The Gravitational force

The changing magnetic field of the changing current causes electromagnetic mass change by the negative electric field caused by the changing acceleration of the electric charge.

The gravitational attractive force is basically a magnetic force.

The same electric charges can attract one another by the magnetic force if they are moving parallel in the same direction. Since the electrically neutral matter is composed of negative and positive charges they need 2 photons to mediate this attractive force, one per charges. The Bing Bang caused parallel moving of the matter gives this magnetic force, experienced as gravitational force.

Since graviton is a tensor field, it has spin = 2, could be 2 photons with spin = 1 together.

You can think about photons as virtual electron – positron pairs, obtaining the necessary virtual mass for gravity.

The mass as seen before a result of the diffraction, for example the proton – electron mass rate $M_p = 1840\ M_e$. In order to move one of these diffraction maximum (electron or proton) we need to intervene into the diffraction pattern with a force appropriate to the intensity of this diffraction maximum, means its intensity or mass. [1]

The Big Bang caused acceleration created radial currents of the matter, and since the matter is composed of negative and positive charges, these currents are creating magnetic field and attracting forces between the parallel moving electric currents. This is the gravitational force experienced by the matter, and also the mass is result of the electromagnetic forces between the charged particles. The positive and negative charged currents attracts each other or by the magnetic forces or by the much stronger electrostatic forces!?

The gravitational force attracting the matter, causing concentration of the matter in a small space and leaving much space with low matter concentration: dark matter and energy.
There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

The Graviton

In physics, the graviton is a hypothetical elementary particle that mediates the force of gravitation in the framework of quantum field theory. If it exists, the graviton is expected to be massless (because the gravitational force appears to have unlimited range) and must be a spin-2 boson. The spin follows from the fact that the source of gravitation is the stress-energy tensor, a second-rank tensor (compared to electromagnetism's spin-1 photon, the source of which is the four-current, a first-rank tensor). Additionally, it can be shown that any massless spin-2 field would give rise to a force indistinguishable from gravitation, because a massless spin-2 field must couple to (interact with) the stress-energy tensor in the same way that the gravitational field does. This result suggests that, if a massless spin-2 particle is discovered, it must be the graviton, so that the only experimental verification needed for the graviton may simply be the discovery of a massless spin-2 particle. [3]

What is the Spin?

So we know already that the new particle has spin zero or spin two and we could tell which one if we could detect the polarizations of the photons produced. Unfortunately this is difficult and neither ATLAS nor CMS are able to measure polarizations. The only direct and sure way to confirm that the particle is indeed a scalar is to plot the angular distribution of the photons in the rest frame of the centre of mass. A spin zero particles like the Higgs carries no directional information away from the original collision so the distribution will be even in all directions. This test will be possible when a much larger number of events have been observed. In the mean time we can settle for less certain
indirect indicators.

The Casimir effect

The Casimir effect is related to the Zero-point energy, which is fundamentally related to the Heisenberg uncertainty relation. The Heisenberg uncertainty relation says that the minimum uncertainty is the value of the spin: 1/2 h = dx dp or 1/2 h = dt dE, that is the value of the basic energy status.

The moving charges are accelerating, since only this way can self maintain the electric field causing their acceleration. The electric charge is not point like! This constant acceleration possible if there is a rotating movement changing the direction of the velocity. This way it can accelerate forever without increasing the absolute value of the velocity in the dimension of the time and not reaching the velocity of the light. In the atomic scale the Heisenberg uncertainty relation gives the same result, since the moving electron in the atom accelerating in the electric field of the proton, causing a charge distribution on delta x position difference and with a delta p momentum difference such a way that they product is about the half Planck reduced constant. For the proton this delta x much less in the nucleon, than in the orbit of the electron in the atom, the delta p is much higher because of the greater proton mass. This means that the electron is not a point like particle, but has a real charge distribution.

Electric charge and electromagnetic waves are two sides of the same thing; the electric charge is the diffraction center of the electromagnetic waves, quantified by the Planck constant h.

The Fine structure constant

The Planck constant was first described as the proportionality constant between the energy (*E*) of a photon and the frequency (*ν*) of its associated electromagnetic wave. This relation between the energy and frequency is called the **Planck relation** or the **Planck–Einstein equation**:

$$E = h\nu \, .$$

Since the frequency ν, wavelength *λ*, and speed of light *c* are related by *λν* = *c*, the Planck relation can also be expressed as

$$E = \frac{hc}{\lambda}.$$

Since this is the source of Planck constant, the e electric charge countable from the Fine structure constant. This also related to the Heisenberg uncertainty relation, saying that the mass of the proton should be bigger than the electron mass because of the difference between their wavelengths.

The expression of the fine-structure constant becomes the abbreviated

$$\alpha = \frac{e^2}{\hbar c}$$

This is a dimensionless constant expression, 1/137 commonly appearing in physics literature.

This means that the electric charge is a result of the electromagnetic waves diffractions, consequently the proton – electron mass rate is the result of the equal intensity of the corresponding electromagnetic frequencies in the Planck distribution law, described in my diffraction theory.

Path integral formulation of Quantum Mechanics

The path integral formulation of quantum mechanics is a description of quantum theory which generalizes the action principle of classical mechanics. It replaces the classical notion of a single, unique trajectory for a system with a sum, or functional integral, over an infinity of possible trajectories to compute a quantum amplitude. [7]

It shows that the particles are diffraction patterns of the electromagnetic waves.

Conclusions

Solitons are localized wave disturbances that propagate without changing shape, a result of a nonlinear interaction that compensates for wave packet dispersion. Individual solitons may collide, but a defining feature is that they pass through one another and emerge from the collision unaltered in shape, amplitude, or velocity, but with a new trajectory reflecting a discontinuous jump. This remarkable property is mathematically a consequence of the underlying integrability of the onedimensional (1D) equations, such as the nonlinear Schrödinger equation, that describe solitons in a variety of wave contexts, including matter waves1, 2. Here we explore the nature of soliton collisions using Bose–Einstein condensates of atoms with attractive interactions confined to a quasi-1D waveguide. Using real-time imaging, we show that a collision between solitons is a complex event that differs markedly depending on the relative phase between the solitons. By controlling the strength of the nonlinearity we shed light on these fundamental features of soliton collisional dynamics, and explore the implications of collisions in the proximity of the crossover between one and three dimensions where the loss of integrability may precipitate catastrophic collapse. [10]

"It's a photonic interaction that's mediated by the atomic interaction," Lukin said. "That makes these two photons behave like a molecule, and when they exit the medium they're much more likely to do so together than as single photons." To build a quantum computer, he explained, researchers need

to build a system that can preserve quantum information, and process it using quantum logic operations. The challenge, however, is that quantum logic requires interactions between individual quanta so that quantum systems can be switched to perform information processing. [9]

The magnetic induction creates a negative electric field, causing an electromagnetic inertia responsible for the relativistic mass change; it is the mysterious Higgs Field giving mass to the particles. The Planck Distribution Law of the electromagnetic oscillators explains the electron/proton mass rate by the diffraction patterns. The accelerating charges explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Relativistic Quantum Theories. The self maintained electric potential of the accelerating charges equivalent with the General Relativity space-time curvature, and since it is true on the quantum level also, gives the base of the Quantum Gravity. The electric currents causing self maintaining electric potential is the source of the special and general relativistic effects. The Higgs Field is the result of the electromagnetic induction. The Graviton is two photons together.

References

[1] http://www.academia.edu/3834454/3_Dimensional_String_Theory

[2] http://www.academia.edu/3833335/The_Magnetic_field_of_the_Electric_current

[3] http://www.academia.edu/4158863/Higgs_Field_and_Quantum_Gravity

[4] http://www.academia.edu/4196521/The_Electro-Strong_Interaction

[5] http://www.academia.edu/4221717/General_Weak_Interaction

[6] The Feynman Lectures on Physics p. 274 (30.6)
Author: Richard Phillips Feynman
Publisher: Addison Wesley Longman (January 1970)
ISBN-10: **0201021153** | ISBN-13: **978-0201021158** [7] Path Integral Formulation of Quantum Mechanics

http://en.wikipedia.org/wiki/Path_integral_formulation

[8] https://www.academia.edu/4215078/Accelerated_Relativity

[9] http://phys.org/news/2013-09-scientists-never-before-seen.html

[10] http://www.nature.com/nphys/journal/vaop/ncurrent/full/nphys3135.html

[11] http://www.sciencedaily.com/releases/2014/11/141102160109.htm

[12] Ultra-cold atoms may wade through quantum friction http://phys.org/news/2016-06-ultra-cold-atoms-wade-quantum-friction.html [13] Study solves 50-year-old puzzle tied to enigmatic, lone wolf waves http://phys.org/news/2016-10-year-old-puzzle-tied-enigmatic-lone.html [14] Scientists develop new method of high-precision optical measurement http://phys.org/news/2016-10-scientists-method-high-precision-optical.html

[15] Inspecting matter using terahertz light https://phys.org/news/2017-08-terahertz.html

[16] ATLAS observes direct evidence of light-by-light scattering
https://phys.org/news/2017-08-atlas-evidence-light-by-light.html

[17] The LEC—now an efficient and bright device
https://phys.org/news/2018-01-lecnow-efficient-bright-device.html

[18] Alternative to traditional batteries moves a step closer to reality after exciting progress in supercapacitor technology
https://phys.org/news/2018-02-alternative-traditional-batteries-closer-reality.html

[19] Evidence of quantum state in spin cluster chain predicted by Nobel Prize recipient found in magnetic mineral
https://phys.org/news/2018-02-evidence-quantum-state-cluster-chain.html

[20] Realizing kagome spin ice in a frustrated intermetallic compound

https://phys.org/news/2020-03-kagome-ice-frustrated-intermetallic-compound.html